AKBP 12: Novel Accelerators I

Time: Thursday 9:30–11:00 Location: SCH/A117

Topical Talk AKBP 12.1 Thu 9:30 SCH/A117

Cutting-edge research and technology at KIT's advanced accelerator facilities — •Erik Bründermann — IBPT Accelerator Team, KIT, Karlsruhe, Deutschland

The Institut für Beschleunigerphysik und Technologie (IBPT) at the Karlsruhe Institute of Technology (KIT) operates a unique suite of accelerator facilities. These include the Karlsruhe Research Accelerator (KARA) with its electron storage ring (0.5-2.5 GeV) and booster synchrotron (50-500 MeV), the short-pulse linear accelerator FLUTE (40-90 MeV), and the KITTEN test center for energy-efficient research infrastructures. In addition, IBPT is developing compact laser-plasma accelerators (LPAs). Together with its Magnet and Cryogenics Facilities of the Accelerator Technology Platform (ATP), KIT offers an outstanding environment for accelerator research and technology transfer. Looking ahead, the compact storage ring cSTART will be established to explore non-linear and non-equilibrium physics, with FLUTE and LPAs serving as injectors.

In this group report, we present the current and upcoming accelerator test facilities at KIT and highlight key results in accelerator physics and technology, including the first superconducting THz undulator, ultra-high-dose operation modes of FLUTE, and innovative diagnostic techniques.

AKBP 12.2 Thu 10:00 SCH/A117

Simulations of a Plasma Booster for the European XFEL — •Anna Krivkova[1], Tianyun Long[1], Alexander Sinn[1], Maxence Thevenet[1], Stephan Wesch[1], Matthew Wing[1,2], and Jonathan Wood[1] — [1]Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Germany — [2]University College London, London WC1E 6BT, United Kingdom

Proposed upgrades of the European XFEL include continuous-wave operation, which requires lowering maximum beam energy from 17.5 GeV to about 8 GeV to facilitate a large increase in repetition rate. A beam-driven plasma accelerator offers a compact and efficient solution to compensate for this energy loss. By integrating a plasma booster into an existing beamline, the European XFEL could restore its nominal beam energy and potentially exceed the current 17.5 GeV limit. To evaluate the feasibility and performance of such a booster, we perform particle-in-cell simulations in HiPACE++ using several gas species over a range of plasma densities. The accelerating gradients consistently reach the multi-GV/m regime, with realistic peak values of about 8 GV/m. The simulations further show that the 5 kA, high-brightness XFEL bunches present challenges for plasma wakefield acceleration due to strong ion motion and beam-induced ionization, increasing the emittance and energy spread of the accelerated witness bunch. Mitigation strategies, including optimization of the initial driver and witness emittance, will be presented.

AKBP 12.3 Thu 10:15 SCH/A117

all-optical In-plasma multi-staging of Laser-Wakefield Accelerators using density tailoring — •Xingjian Hui, Alberto Martinez de la ossa, Alexander Sinn, Ángel Ferran pousa, Rob Shalloo, and Maxence Thévenet — DESY, Hamburg, Germany

The staging of laser-driven plasma accelerators (LPAs) could open up energy frontiers, but achieving in- and out-coupling of laser pulses while preserving beam quality remains a challenge. In this work, we present an all-optical, in-plasma staging scheme that uses refraction in a transverse plasma density gradient to couple the incoming laser into the next LPA stage, eliminating the need for mirrors and magnets. This design can in principle support significant ion motion without substantial emittance degradation, making it well-suited for a broad energy range. With realistic 3D simulations using the quasistatic particle-in-cell code HiPACE++ on GPU, we observe 98% capture efficiency and 15+3+3 GeV energy gain per within 3 stages with emittance preserved and proper bean loading, driven by a ~20J for first stage and ~10 J laser pulse for followings guided by a hydrodynamic optical-field-ionized (HOFI) channel of matched spot size 30 microns. These results represent a significant step toward practical multistage plasma acceleration, paving the way for the generation of ultra-high-energy electron beams for a wide range of scientific and technological applications.

AKBP 12.4 Thu 10:30 SCH/A117

Microsecond-timescale plasma density growth by electron beam energy deposition in plasma-wakefield accelerators — •Judita Beinortaite[1], Jonas Björklund Svensson[1], Lewis Boulton[1], Greg Boyle[2], Brian Foster[1,3], Pau González Caminal[1], Harry Jones[1], Advait Kanekar[1,4], Anna Křivková[1], Gregor Loisch[1], Jens Osterhoff[1], Felipe Peña[1,4], Sarah Schröder[1], Stephan Wesch[1], Matthew Wing[1,5], Jonathan Wood[1], and Richard D'Arcy[1,3] — [1]DESY, Germany — [2]James Cook University, Australia — [3]J.A.I, UK — [4]University of Hamburg, Germany — [5]University College London, UK

High-repetition-rate operation of plasma-wakefield accelerators is essential for their suitability in the design of particle colliders and Free-Electron Lasers (FELs). Energy remaining in the plasma after the wakefield acceleration event can limit the repetition rate of the plasma accelerator as the plasma takes time to relax to its initial state. This relaxation is dominated by two ion-driven effects: their redistribution after the wakefield event and potential further collisional ionisation caused by this motion. In this work, we investigated argon plasma at a variety of working points with two different diagnostics: the pump-probe electron-beam-based technique and optical-emission spectrometry. In some regimes, both diagnostics indicated additional ionisation occurring on the nanoseconds-to-microsecond timescale for specific initial plasma conditions, which increased the recovery time. This can inform the design of the highest-repetition-rate plasma sources for future colliders and FELs.

AKBP 12.5 Thu 10:45 SCH/A117

Radiation Signatures from Injection Lasers in Plasma Wakefield Accelerators — •Finn-Ole Carstens[1,2], Alexander Debus[1], Klaus Steiniger[1], Michael Bussmann[1], Fabia Dietrich[1,2], Maxwell LaBerge[1], Susanne Schoebel[1], Jessica Tiebel[1,2], Patrick Ufer[1,2], Nico Wrobel[1,2], Arie Irman[1], Ulrich Schramm[1,2], and Richard Pausch[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany — [2]Dresden University of Technology, Dresden, Rossendorf

Plasma-wakefield acceleration driven by electron beams from laser-wakefield accelerators enables compact, two-stage schemes of electron accelerators. The trojan horse injection method uses a transverse, femtosecond laser pulse to ionize electrons inside the first plasma cavity and promises high-brightness electron bunches. Unexpectedly, experiments showed a distinct radiation feature in shadowgraphy images whenever this injection laser interacted with the plasma wake. This effect that turned out to be crucial for timing calibration but was not understood.

We investigate this signal using particle-in-cell simulations equipped with an in-situ imaging plugin based on Fourier propagation, which models the shadowgraphy diagnostic directly during runtime. This approach allows tracing the formation of the observed feature and reveals that it originates from Thomson scattering of the injection laser of the sheath electrons of the PWFA cavity. In this contribution, we present the mechanism behind the signal and show how it can be used to infer structural properties of the plasma cavity.